Active Astronomy:
Classroom Activities for Learning About Infrared Light

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STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY
DEVELOPED AND OPERATED FOR NASA BY USRA

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We would like to thank the following pilot test teachers and their students, informal educators, education facilitators, and astronomers who reviewed or tested *Active Astronomy: Classroom Activities for Learning About Infrared Light*. Their critical comments and recommendations based on nationwide classroom use of these activities contributed to this teacher's guide. Their participation in the pilot does not necessarily imply endorsement of the guide. Their recommendations were invaluable and have been recorded and integrated into the activities. We especially appreciate the students' input. Thank You!

The Montana State University Conceptual Astronomy and Physics Education Research (CAPER) Activities Development Team worked in partnership with Stratospheric Observatory For Infrared Astronomy (SOFIA) Education and Public Outreach staff developing this teacher's guide. The evaluation team at the Space Telescope Science Institute provided the helpful preliminary review, prior to field testing in school classrooms. We would also like to thank Sven Kohle and Till Credner at the Astronomical Institutes of the University of Bonn, for the use of the Crab Nebula image. Thanks everyone.

SOFIA is being developed and operated for NASA by the Universities Space Research Association (USRA). The SETI Institute and the Astronomical Society of the Pacific lead the Education and Outreach Program for SOFIA.

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Stratospheric Observatory for Infrared Astronomy SOFIA

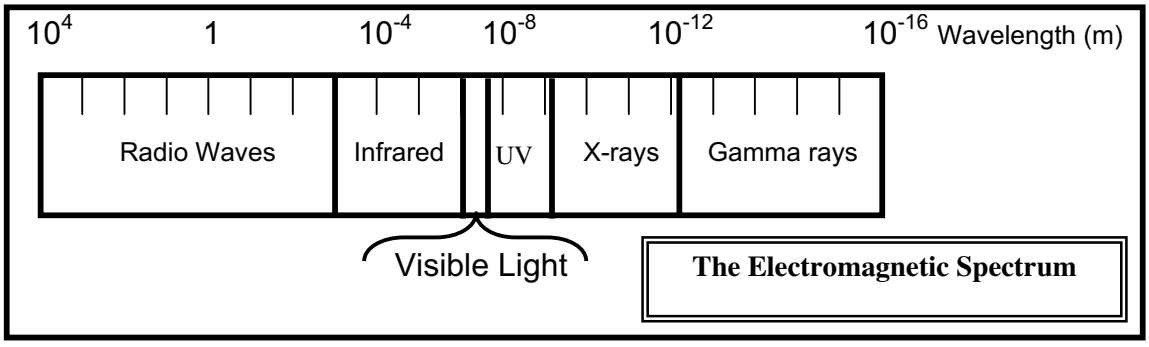
Active Astronomy
Classroom Activities for Learning about Infrared Light

1.1 For the Teacher

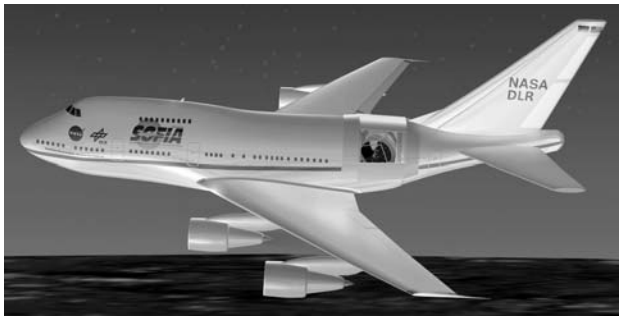
Most students are familiar with the rainbow of colors that make up visible light. They're often less comfortable dealing with light from the other portions of the electromagnetic spectrum — gamma rays, x-rays, ultraviolet light, visible light, infrared light, microwaves, and radio waves. Students may not realize the important role played by non-visible light in their everyday lives. For example, TV remote controls, car-locking systems, and some grocery store check-out scanners use infrared light to signal between devices or read bar-codes. Computers use infrared light to read CD-ROMs. Night-vision goggles register infrared light (also known as heat radiation), as do search-and-rescue monitors that look for the heat given off by someone lost in the wilderness at night.

The activities in "Active Astronomy: Classroom Activities for Learning about Infrared Light" focus on improving student understanding of infrared light, which occupies the portion of the electromagnetic spectrum between visible light and microwaves, the shortest of the radio waves.

It is appropriate to refer to each portion of the electromagnetic spectrum as "light." All forms of light—from the lowest energy radio waves to the highest energy gamma rays—can be described as waves. The major difference distinguishing one from the other is wavelength; the shortest wavelength gamma rays have a wavelength about the size of the atomic nucleus, whereas the wavelength of radio waves from FM 101 is about 3 meters. Visible light is only a small part of the electromagnetic spectrum with wavelengths ranging from 0.4 to 0.7 microns (a micron is a millionth of a meter). The wavelengths of light in the infrared region vary from about 1 to 350 microns.



To understand the universe, astronomers must observe at all wavelength regions, including the infrared. However, water vapor in the Earth's atmosphere absorbs infrared light, keeping it from reaching telescopes on the ground (some narrow bands of infrared light do reach the ground and can be observed from the tops of high mountains). To study infrared emissions from space, astronomers have put telescopes in airplanes, which can fly high above most of the water vapor in the atmosphere, or in space.



The Stratospheric Observatory for Infrared Astronomy (SOFIA), developed by NASA and the German Aerospace Center, DLR, is the latest in a series of "flying telescopes." For SOFIA, technicians modified a Boeing 747SP aircraft to carry a 2.5-meter (8.2-foot) infrared telescope that observes the sky through a hole in the side of the airplane. When fully operational, SOFIA will be the largest airborne telescope in the world, and will make observations that are impossible for even the largest and highest of ground-based telescopes. SOFIA will observe the universe from visible (0.3 microns), through infrared (1 to 350 microns), and microwave (1600 microns) wavelengths.

Every object that has a temperature above absolute zero (0 K) emits energy in the infrared region of the spectrum. Infrared astronomy covers nearly everything in the universe. Objects too cool or too faint to be seen in visible light, such as dim, cool stars and interstellar dust particles, can be studied in the infrared. Infrared light can penetrate deep into interstellar clouds of dust and gas that block visible light, revealing astronomical phenomena that would otherwise be obscured from view. Because of this, astronomers interested in exploring the interstellar clouds that serve as the birthplaces of stars observe them in infrared light.

Previous ground-based, satellite and airborne infrared observatories have explored the infrared region of the spectrum. SOFIA will exploit and extend this scientific legacy with instruments that reveal even greater details in spectra and photographs taken in the infrared. Topics to be addressed by SOFIA scientists include:

- how stars form and evolve over time;
- how planets form around stars;
- the conditions in space between stars;
- the origin and evolution of the complex atoms and molecules important to life;
- the study of comets, planetary atmospheres and rings in the Solar System;
- how other galaxies compare to our own Milky Way Galaxy;
- the dynamic activity surrounding the super massive black hole in the center of the Milky Way Galaxy.

SOFIA is a mission in NASA's Origins Program (http://origins.jpl.nasa.gov). The Origins Program asks questions humans have pondered for centuries: Where do we come from? Are we alone? Additional information about SOFIA and its astronomical research can be found at the SOFIA web site: http://www.sofia.arc.nasa.gov.

The Activities

These activities are designed to *supplement* classroom instruction about the electromagnetic spectrum, and are not intended as a complete curriculum. The activities in this packet have been designed for use with middle school and high school physical science, astronomy and space science courses. Each activity has been designed to take 1-2 class periods (see the individual activities for more details about activity length). The activities are:

What's Getting Through to You?

Students are introduced to light and colored filters(gels), and learn about the usefulness of filters to astronomers.

Sensing the Invisible

Just as our ears cannot hear all wavelengths of sound, our eyes cannot see all wavelengths of light. Students learn that "invisible light" exists and that we can detect this light with instruments other than our eyes.

Reflection

Students learn that infrared light is reflected in the same manner as visible light. Students deduce that infrared light is another form of light and is a part of the electromagnetic spectrum.

Listening to Light

Students learn that light carries information and that infrared radiation is a form of light that in some cases behaves like visible light and other cases behaves very differently.

Student Prerequisites and Common Misconceptions

- Students are assumed to be familiar with the visible spectrum before beginning these activities, and to have some knowledge of the electromagnetic spectrum and how it relates to the visible spectrum.
- Students are assumed to have some familiarity with the idea of reflected, absorbed, and transmitted light, and to understand the terms "opaque" and "transparent."
- Students may not realize that light travels from one object to another. This may create problems for students in understanding the material in these activities. Teachers may want to address this misconception in their teaching.

  "Many elementary- and middle-school students do not believe that their eyes receive light when they look at an object. Students' conceptions of vision vary from the notion that light fills space ('the room is full of light') and the eye 'sees' without anything linking it to the object to the idea that light illuminates surfaces that we can see by the action of our eyes on them… The conception that the eye sees without anything linking it to the object persists after traditional instruction in optics; however, some 5th graders can understand

seeing as 'detecting' reflected light after specially designed instruction." *Benchmarks for Science Literacy*: p. 339.

- Students are assumed to have some familiarity assembling and working with electronic circuits.

Science Standards

These activities support the following standards and benchmarks:

National Science Education Standards — Grades 5-8

Content Standard A: Abilities necessary to do scientific inquiry (NSES, page 145)

- Use appropriate tools and techniques to gather, analyze, and interpret data
- Develop descriptions, explanations, predictions, and models using evidence

Content Standard B: Physical Science, Transfer of Energy (NSES, page 155)

- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.

- The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Content Standard E: Science and Technology (NSES, page 166)

- Science and technology are reciprocal. Science helps drive technology as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and techniques. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size and speed. Technology also provides tools for investigations, inquiry and analysis.

National Science Education Standards — Grades 9-12

Content Standard A: Abilities necessary to do scientific inquiry (NSES, page 175)

- Formulate and revise scientific explanations and models using logic and evidence

Content Standard B: Physical Science (NSES, page 180)

- Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, x-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Benchmarks for Science Literacy — Grades 6-8

The Physical Setting, 4f: Motion (pages 90-92)

- Light from the sun is made up of a mixture of many different colors of light, seen though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors.

- Human eyes respond to only a narrow range of wavelengths of electromagnetic radiation—visible light. Differences of wavelength within that range are perceived as differences in color.

Benchmarks for Science Literacy — Grades 9-12

The Physical Setting, 4f: Motion (page 92)

- Waves can superimpose on one another, bend around corners, reflect off of surfaces, be absorbed by materials they enter, and change direction when entering a new material. All these effects vary with wavelength. The energy of waves (like any form of energy) can be changed into other forms of energy.

Hardware and Materials Needed

These activities are designed to use easy-to-obtain materials. Information on where to obtain materials and components is listed in section 1.5.

For demonstrations (one set of materials & hardware required):

- Photocell Detector
  - Photocell (solar cell)—NOTE: Photocells may not be in stock at local electronic parts stores. But they can be special ordered, or ordered directly online or by phone (see section 1.5 for more information). *Allow at least a week for delivery*.
  - Amplifier/Speaker
  - 9-Volt battery for amplifier/speaker
  - Audio Cable with 1/8" mini-plug on one end
  - Two Jumper Cables with alligator clips on both ends
- Transmitter Circuit
  - Infrared Light-Emitting Diode (LED)
  - 0.22 μF (microfarad) Capacitor
  - Audio Cable with 1/8" mini-plug on one end
  - 5 Jumper Cables with alligator clips on both ends
  - AA Battery
  - AA Battery Holder
- Large magnifying glass, with focal length around 15 cm (fairly standard)
- Flashlight
- Laser pointer (or other laser device)
- Collection of remote control devices (TV, VCR) from several different manufacturers
- Sony Walkman, transistor radio or other music source
- Clear plastic bag
- Colored plastic bag

- Tissue
- Piece of paper
- Piece of cardboard
- Phillips screw driver

The materials needed for *each group of students* to complete all four activities are:

- White paper
- Black and red construction paper
- Red and blue crayons
- Red and blue gels
- Internet access or downloaded versions of images mentioned (Crab Nebula, visible bag, IR bag, multiband logo)
- Slide projector or overhead projector
- Diffraction grating (handle with gloves) or prism
- Fan
- Masking Tape
- Slide Mount
- Undeveloped exposed photographic film
- Red and green gels
- TV or VCR remote controls (with working batteries) from different manufacturers
- 1-4 mirrors (the larger the better) A way to mount the mirrors so they stay in place (e.g., tape to boxes, tape to wall, lumps of clay, etc.)

CREDITS

These activities were developed in partnership with the Montana State University Conceptual Astronomy and Physics Education Research (CAPER) Team.

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SOFIA is being developed and operated for NASA by a team led by the Universities Space Research Association (USRA). The SETI Institute and the Astronomical Society of the Pacific lead the Education and Public Outreach Program for SOFIA. For further information, please visit: http://www.sofia.arc.nasa.gov

Directions: Write all of your answers on the answer sheet. Do NOT Write on the test.

Matching: On your answer sheet, you will find diagrams. Match the diagrams to the following terms. Mark you answer on the answer sheet, not on the test.

1. Reflection
2. Transmission
3. Absorption
4. Emission

Multiple Choice: Select the one best answer for each question. Mark your answer on the answer sheet.

5. Which of the following best describes why infrared telescopes enable observations that are not possible with visible light telescopes?
    A. Infrared light is less harmful than visible light.
    B. Visible light travels slower than infrared light.
    C. Infrared light will pass through the stellar dust clouds.
    D. All of the above

6. What colors of light make up the light from the sun?
    A. Red, Yellow, Blue, White, and Black
    B. White and Yellow
    C. Red, Orange, Yellow, Green, Blue, Indigo, and Violet
    D. White and Black

7. Which of the following best describes the speed of infrared light?
    A. Faster than the speed of visible light
    B. Same as the speed of visible light
    C. Slower than the speed of visible light
    D. None of the above

8. Which of the following describes electromagnetic energy interacting with matter?
    A. Interrupted infrared red light on a solar cell connected to an amplifier
    B. White light passing through a green filter
    C. Microwaves hitting a telescope
    D. All of the above

9. Which of the following is a common use of infrared light?
    A. Tanning lamp
    B. Remote control
    C. Street light
    D. Microwave oven

Directions: Write all of your answers on the answer sheet. Do NOT Write on the test.

10. A blue object viewed in red light appears
    A. Blue
    B. Red
    C. Purple
    D. Black

Short Answer: Answer all parts of the questions in the spaces provided on the answer sheet. You do not have to answer in complete sentences.

11. On the answer sheet, fill in the blanks with the names of the different kinds of electromagnetic waves, in order of increasing wavelength.

12. On the answer sheet, complete the diagram to explain what color the viewer observes. Please write a few sentences to explain the diagram.

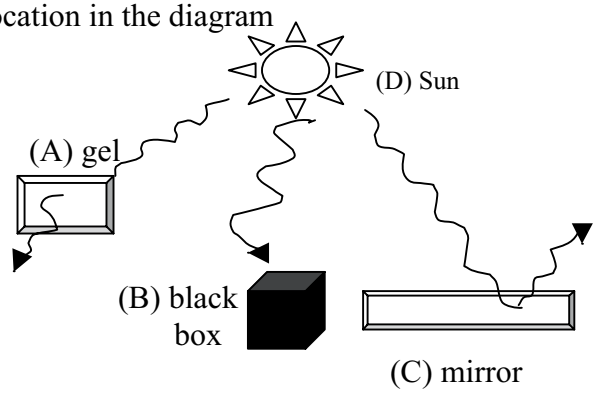
Name: _____

1.3 Student Answer Sheet—Learning about Infrared Light

Directions: Write all of your answers on this answer sheet. Do NOT Write on the test.

Matching: Below is a diagram. Mark you answer on the answer sheet, not on the test. Circle the letter that corresponds to the question items location in the diagram

1. Reflection	A	B	C	D
2. Partial Transmission	A	B	C	D
3. Absorption	A	B	C	D
4. Emission	A	B	C	D



Multiple Choice: Circle the letter of the one best answer for each question.

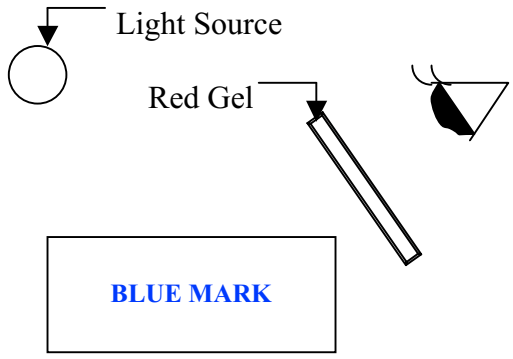
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10	A	B	C	D

Short Answer: Answer all parts of the questions in the spaces provided on the answer sheet. You do not have to answer in complete sentences.

11. _____, _____, _____, _____, _____

_____, _____

12. Explain what color the viewer observes. You may also use a few sentences to clarify your answer.



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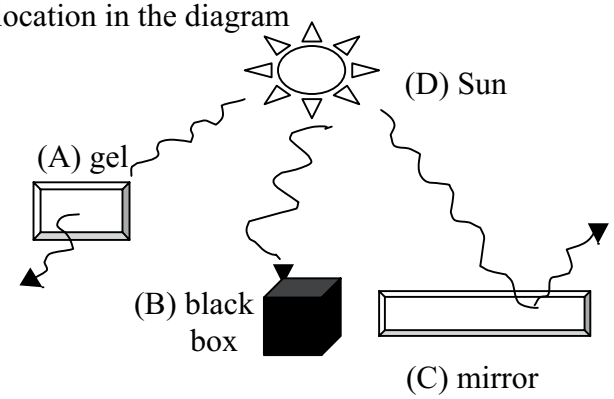
Directions: Write all of your answers on this answer sheet. Do NOT Write on the test.

Matching: Below is a diagram. Mark you answer on the answer sheet, not on the test. Circle the letter that corresponds to the question items location in the diagram

1. Reflection	A	B	**C**	D
2. Partial Transmission	**A**	B	C	D
3. Absorption	A	**B**	C	D
4. Emission	A	B	C	**D**



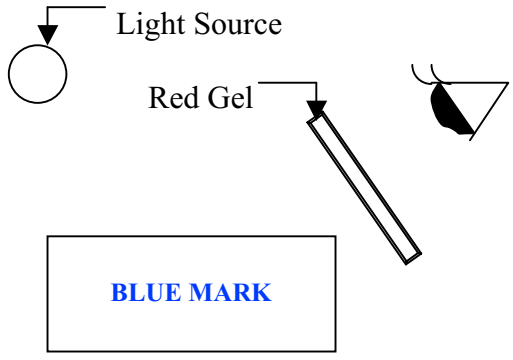
Multiple Choice: Circle the letter of the one best answer for each question.

5.	A	B	**C**	D
6.	A	B	**C**	D
7.	A	**B**	C	D
8.	A	B	C	**D**
9.	A	**B**	C	D
10	A	B	C	**D**

Short Answer: Answer all parts of the questions in the spaces provided on the answer sheet. You do not have to answer in complete sentences.

11. gamma, x-ray, ultra-violet light, visible light, infrared light, microwave, radio

12. Explain what color the viewer observes. You may also use a few sentences to clarify your answer.



Through the red gel, the student will only be able to see the blue mark. The red filter absorbs the blue light that is reflected by the blue mark. Therefore, no light reaches the eye from the mark, the blue will appear black.

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MATERIALS AND PREPARATION

CLASSROOM MATERIALS

CRAYONS

Suggested colors for the red and blue crayons, respectively, are: Crayola orange-red, violet red, blizzard blue, and aquamarine.

MAGNIFYING GLASS

Magnifying lens may be purchased in a set or individually, from:

Sargent Welch**
P.O. Box 5229
Buffalo Grove, IL 60089-5229
Phone: (800) 727-4368
http://www.sargentwelch.com

5 cm diameter bifocal, plastic (Item # WLS 44501) Cost: $3.95
5 cm diameter economy, plastic (Item # WL 8068) Cost: $1.60
Lens set: A set of 20 lenses 50 mm in diameter (10 each of 285 mm focal length, and 10 each of 96 mm focal length) This set is also used in the "More than Magnifiers" GEMS activity.
(Item # WL53200-38L) Cost: $19.99

Flinn Scientific Inc
P.O. Box 219
Batavia, IL 60510
Phone: (800) 452 –261
http://www.flinnsci.com/

Plastic Magnifier Dual Lens (Item # AB1134) Cost: $1.75

SPECIAL MATERIALS

DIFFRACTION GRATING

Holographic diffraction gratings can be purchased as a roll (6 feet x 5 inches) for $38 or in 5 x 5 inch sheets (2 sheets for $9) from:

Learning Technologies, Inc.**
40 Cameron Avenue
Somerville, MA 02144
Phone: (800) 537-8703 or (617) 628-1459
Fax: (617) 628-8606 fax
http://www.starlab.com

Or in a 12cm square, mounted between glass plates (Item #WL3820) for $46.76 from:

Sargent Welch
P.O. Box 5229
Buffalo Grove, IL 60089-5229
Phone: (800) 727-4368
http://www.sargentwelch.com

ELECTRONIC ITEMS

The following items can be found at your local electronic parts store.

AA BATTERY HOLDER
This battery holder should have wire connectors

AMPLIFIER/SPEAKER
200 mWatt speaker (Input sensitivity 1mV, Input impedance 5k,
distortion (1kHz) < 2% THD @ 200mW, Frequency Response 100 Hz – 10 kHz)
This is the most expensive part for the detector, typically costing $11.99.

AUDIO CABLE
Audio cables must have a 1/8" mini-plug on at least one end. We prefer audio cable that has a mini-plug on one end, and exposed wires on the other (easier to connect with the jumper cables), but mini-plugs on both ends will work too. Note that a Y-Adapter Audio Cable will not work in this activity. Audio Cables typically cost around $3 - $4.

CAPACITOR
Sub mini PC mount with radial leads, 0.22 μF, 50 WVDC max.

JUMPER CABLES
Be sure to get cables with mini-alligator clips on both ends.

LED
This Infrared Light Emitting Diode (LED) emits IR with a peak wavelength of 940 nm (0.94μm).

The vendors and Item # for these electronic parts are:

Radio Shack**
at local Radio Shack stores
Phone: (800) the-shack
http://www.radioshack.com

AA battery holder (Item #270-401) Cost ~ $0.89
Amplifier/Speaker (Item #277-1008C) Cost: $11.99
Audio cable (Item #42-2434 or 42-2378) Cost: $3-$4
Capacitor (0.22 μF) (Item #272-1070) Cost ~ $0.89

Jumper cables (Item #278-1157) Cost for a bag of eight: $3.99
LED (Item #276-143 or #276-142) Cost ~ $1.79

Philmore-DATAK
3660 Publishers Drive
Rockford, IL 61109
Phone: (800) 645-2262
http://www.philmore-datak.com
Call for pricing

Infrared LED (Item #11-681)
Audio cable 1/8" mini to tinned leads (Item #CA48)
Jumper lead set (Item #SA22)

Mouser Electronics
1000 North Main St.
Mansfield, TX 76063
Phone: (800) 346-6873
http://www.mouser.com

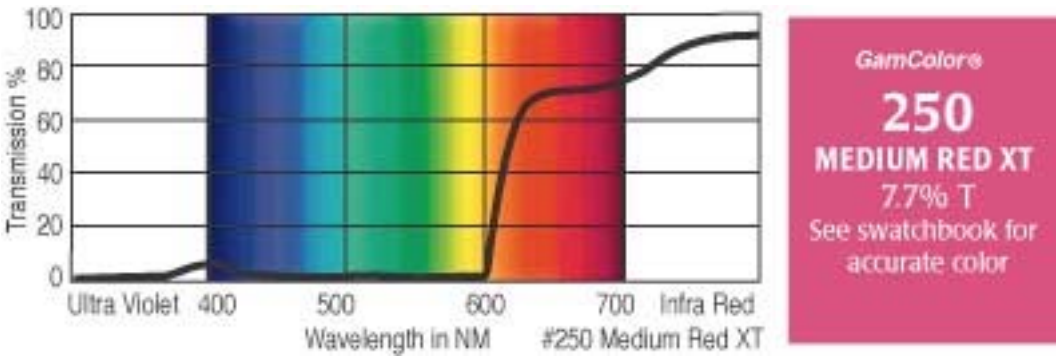
AA Battery Holder (Item #534-2465) Cost: $0.58
Capacitor (Item #140-PM2A224K) Cost: $0.36
Amplifier/Speaker: For those electronically inclined, speaker parts may be purchased and assembled into a mini amp/speaker.

GELS

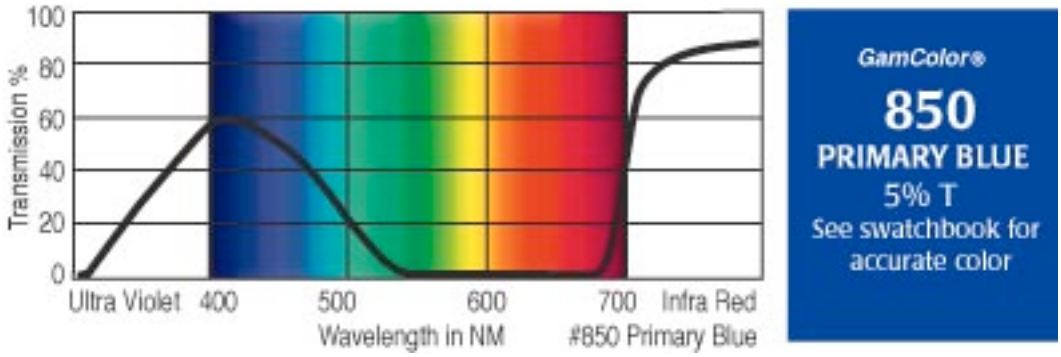
Theatrical gels (filters) are normally used to change the colors of lights in the theater, film, and television work. Because of the need for reliable color, these gels are made to exacting specifications with regard to which wavelengths of light they transmit and which ones they absorb. You can buy gels at a local theatrical supply store, or directly from the companies listed below.

We recommend the following gels (filters), shown with the light transmission curve (percent of light transmitted at each wavelength) for each:

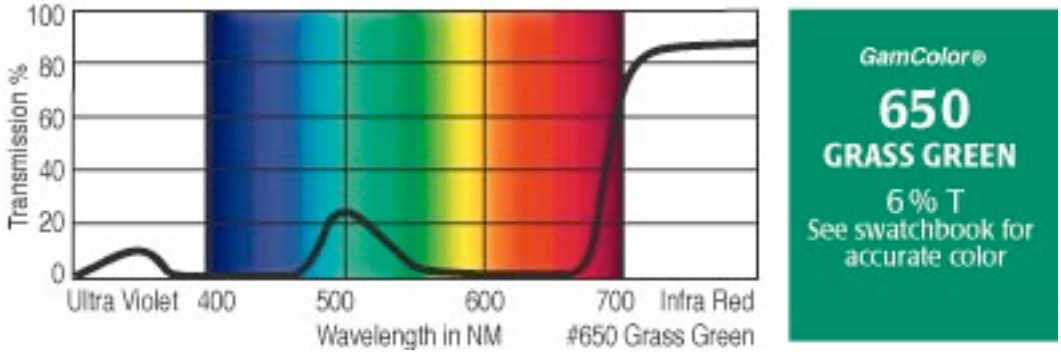
GamColor #250 Medium Red XT



GamColor #850 Primary Blue



GamColor #650 Grass Green



These gels can be obtained from:

Great American Market (GamProducts, Inc.)**
826 N. Cole Avenue
Hollywood, CA 90038
Toll-free phone:(888)GAMCOLOR
Phone: (323)461-0200
Fax: (323)461-4308
http://www.gamonline.com/index.php

The web site lists local dealers of their products. Filters cost $6.25 for a 20-inch by 24-inch sheet, the smallest size available. You can also get a “junior roll” that corresponds to nearly 10 sheets (24 inches by 198 inches) for $49.95.

Mainstage Theatrical Supply, Inc distributes GAM Color Gels.

Two locations:
Milwaukee, WI
Phone: (800) 236 0878
Pensacola, FL
Phone: (800) 851 3618
Online: http://www.mainstage.com/Catalogs.html

If your local supplier does not carry GamColor filters, you can find acceptable substitutes from among the following products (with recommended filter numbers for each):

Roscolux Filters
Rosco USA
52 Harbor View
Stamford, CT 06902
Toll-Free Phone: (800)767-2669
Phone: (203)708-8900
Fax: (203)708-8919

#80 Primary Blue
#27 Medium Red
#389 Chroma Green

For information on filters:
http://www.rosco-ca.com/products/filters/index.cfm?fuseaction=Roscolux#Color
To find local dealers of Roscolux filters:
http://www.rosco-ca.com/intl/top_offices.html
Note that Cinegel filters are also made by Roscolux

Or

LEE Filters
2237 N. Hollywood Way
Burbank, CA 91505
Phone: (800)576-5055
Fax: (818)238-1228
http://www.leefilters.com/home.asp

#106 Primary Red
#079 Just Blue
#139 Primary Green

Note that you can compare the light transmission curves for these alternative filters (many available online) with those of the recommended GamColor gels. If you use an alternative filter, try to match the transmission curves as closely as possible. You want filters that transmit as much blue or red light as possible, with as little light with other wavelengths transmitted as you can get.

SOLAR CELLS

The solar cell in this application is an encapsulated mini solar panel. The vendors and part numbers are:

Solar World**
2807 North Prospect
Colorado Springs, CO 80907
http://www.solarworld.com
Phone: (719) 635-5125
Fax: (719) 635-5398
Solar Cell 0.5A at 0.5V, 3" x1 3/4 " (Item #3-300) Cost: $6.00

Silicon Solar
LLC 16 Winkler Rd.
PO Box 225
Sidney, NY 13838
http://www.siliconsolar.com/solar_cells.htm
Solar Cell .42 A at .58 V 25mm x 62.5mm (Item #SS SC 400)
Cost: $2.25

Ward's Natural Science
http://www.wardsci.com/
Phone: (800) 962-2660
Solar Cell 0.2 A at 0.45 V 2" x 4" (Item #16 V 0508) Cost: $8.75

****vendor products pilot tested**

PREPARATION

Detailed preparation instructions are in each teacher note section. The information below is supplemental.

2.1 "What's Getting Through to You "

Slide sized sections of the gels can be mounted into a piece of cardboard for each student. The images can be downloaded and printed as overhead slides, in lieu of internet access during class.

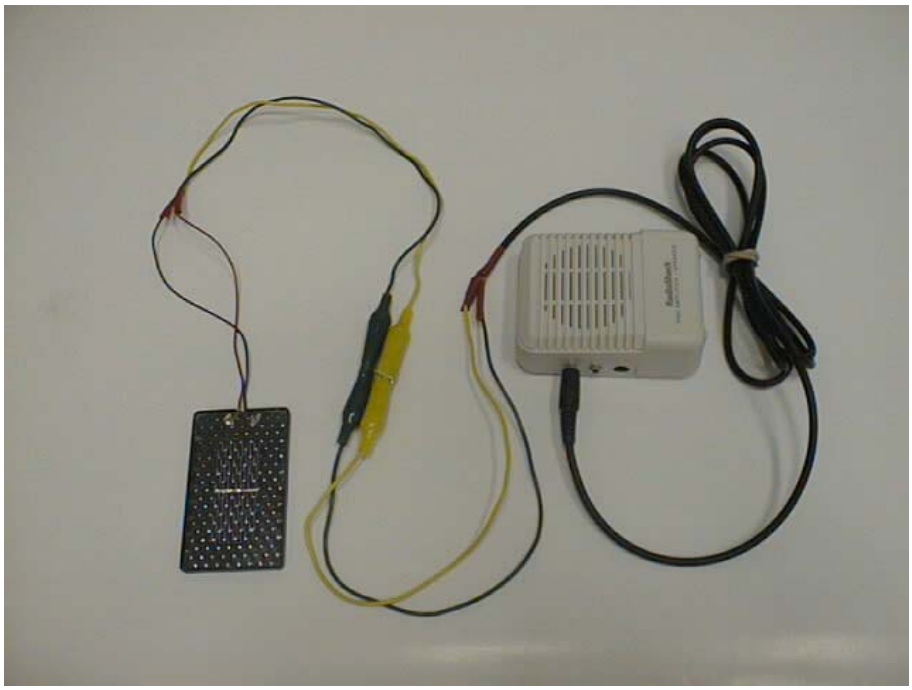
4.1 "Reflection"

The reflection activities are more successful with stable mounted mirrors. Wood blocks with grooves or kerfs, or modeling clay are recommended.

3.1 ”Sensing the Invisible” and 5.1 “Listening to Light”

This material package contains materials for one each photocell detector receiver and transmitter circuits, for demonstration. For student teams, additional materials may be purchased as indicated above. The Teacher Notes in Sections 3.1, and 5.1 contain detailed assembly instructions for the photocell detector receiver and transmitter circuits. Hard metal to metal connections to complete the circuits, and very fresh batteries are key to the success of the activities.

As stated in the teacher notes, the audio cable leads can be connected directly to solar cell leads. If soldering materials or wire nuts are not available, hook and twist the leads together and insulate with electrical tape. Similarly, the jumper leads can be cut in half, wire stripped and connected to the battery holder, and to the second audio cable (for the sound source). The alligator clip to alligator clip connections must be head on and insulated as shown below.



OVERVIEW

Table of Vendors

Item:	Vendor:	Alternate vendor(s):
diffraction grating	Learning Technologies	Sargent Welch
electronic items	Radio Shack	Philmore-DATAK, Mouser Electronics
gels	GAM Products, Inc.	Roscolux Filters, LEE Filters
magnifying glass	Sargent Welch	Flinn Scientific Inc.
solar cells	Solar World	Silicon Solar, Ward’s Natural Science

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